

THMC RESPONSE IN ENHANCED GEOTHERMAL RESERVOIRS

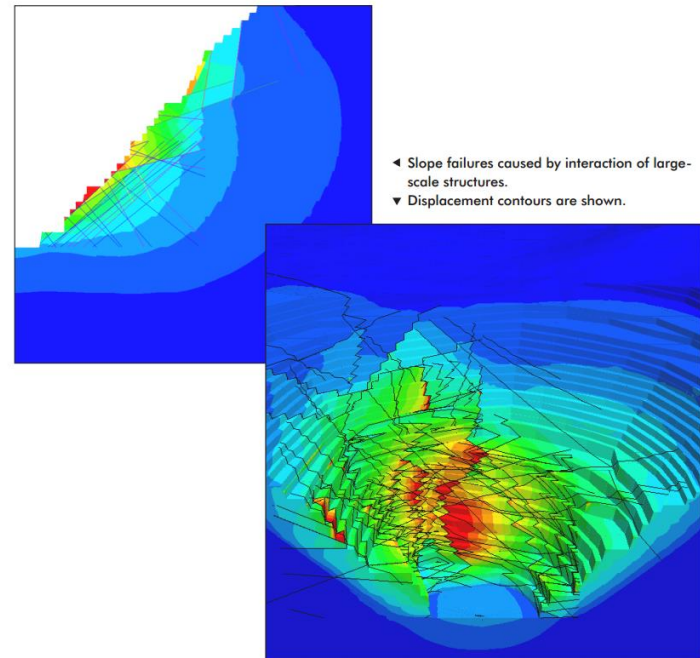
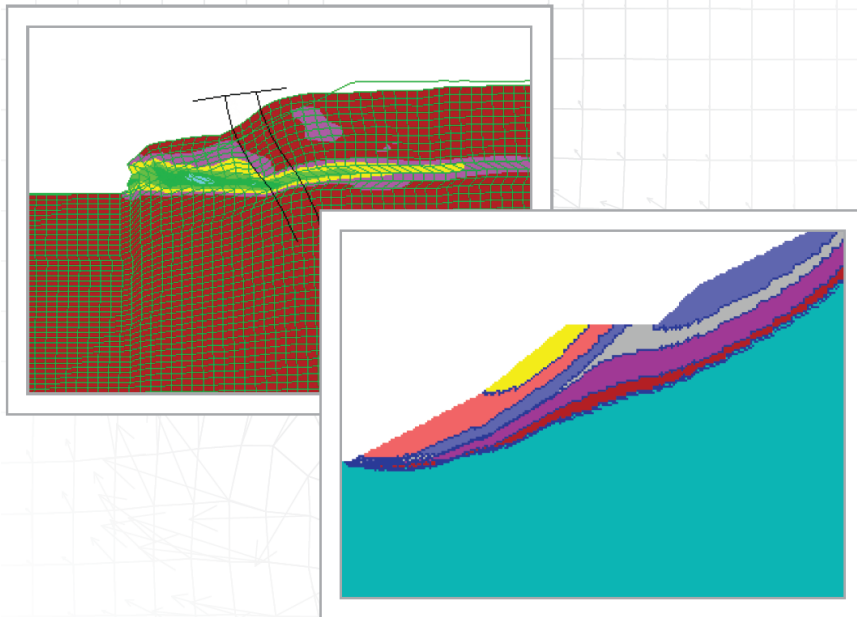
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Overview

- Itasca Code Overview
- Application of UDEC / 3DEC to EGS.

Two code families

- *FLAC* & *FLAC3D* – continuum
- *UDEC*, *3DEC* & *PFC* – discrete





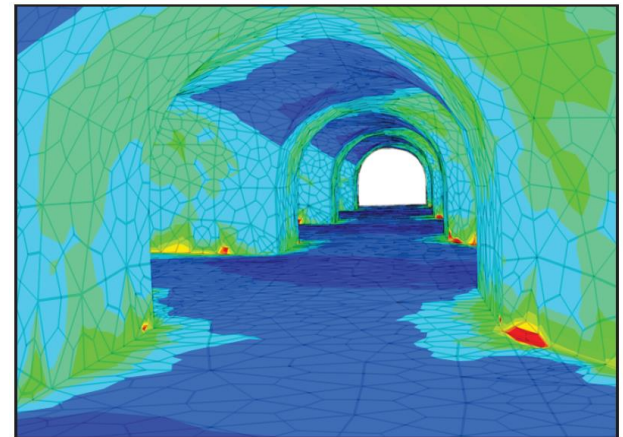
Fish

- Windows specific
- Shared memory
- Scripting



FLAC & FLAC3D

- Specializes in modeling large deformations of non-linear materials and interaction with structures.
 - Explicit time integration
 - Lagrangian formulation
- Dynamic analysis
- Creep constitutive behavior
- Fluid and thermal analysis
- Full coupling

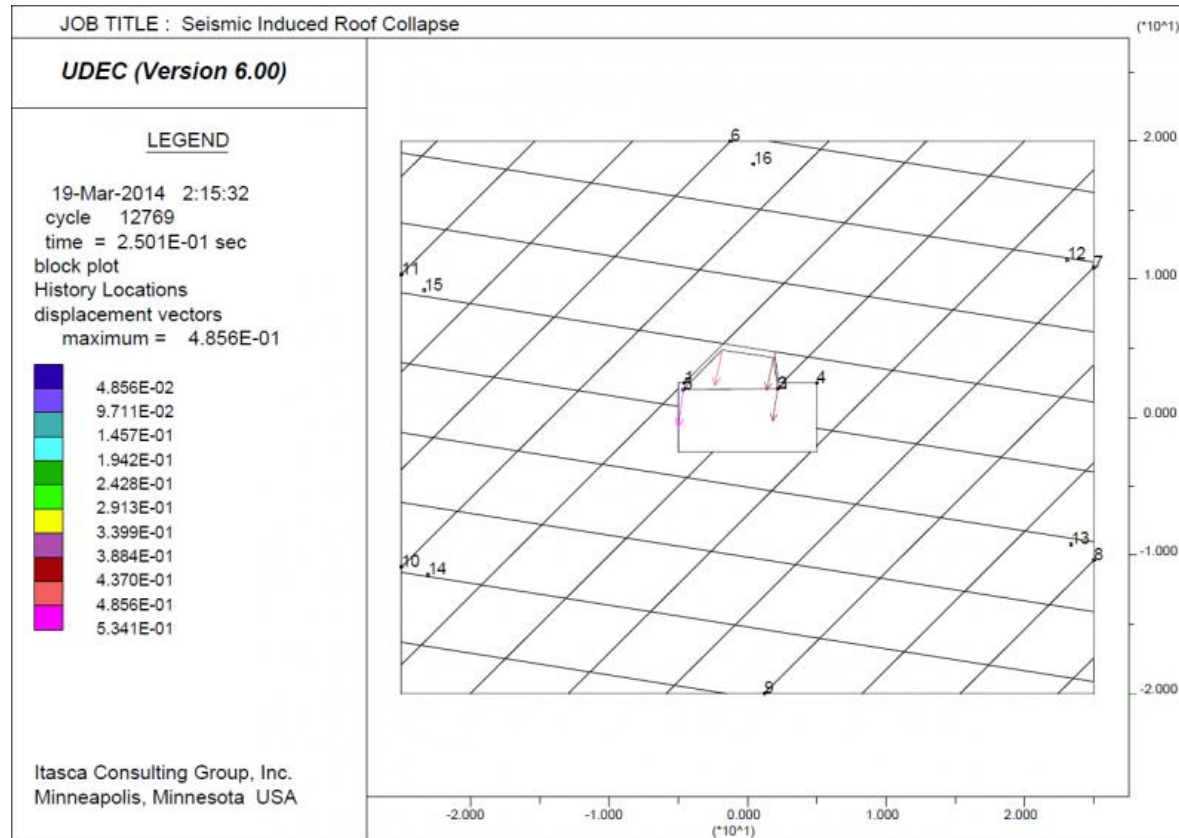


Limitation: Representing discontinuities

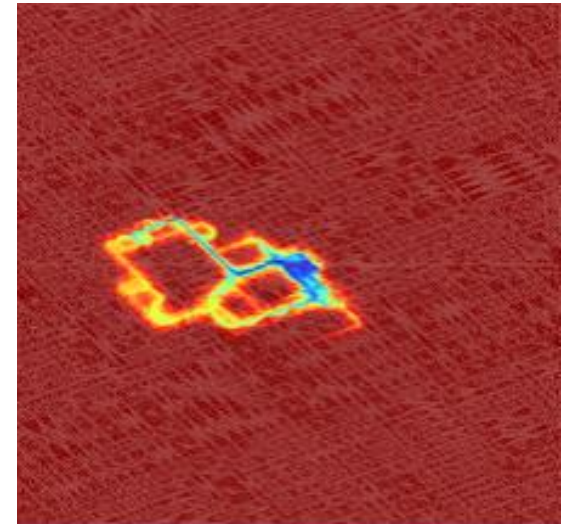
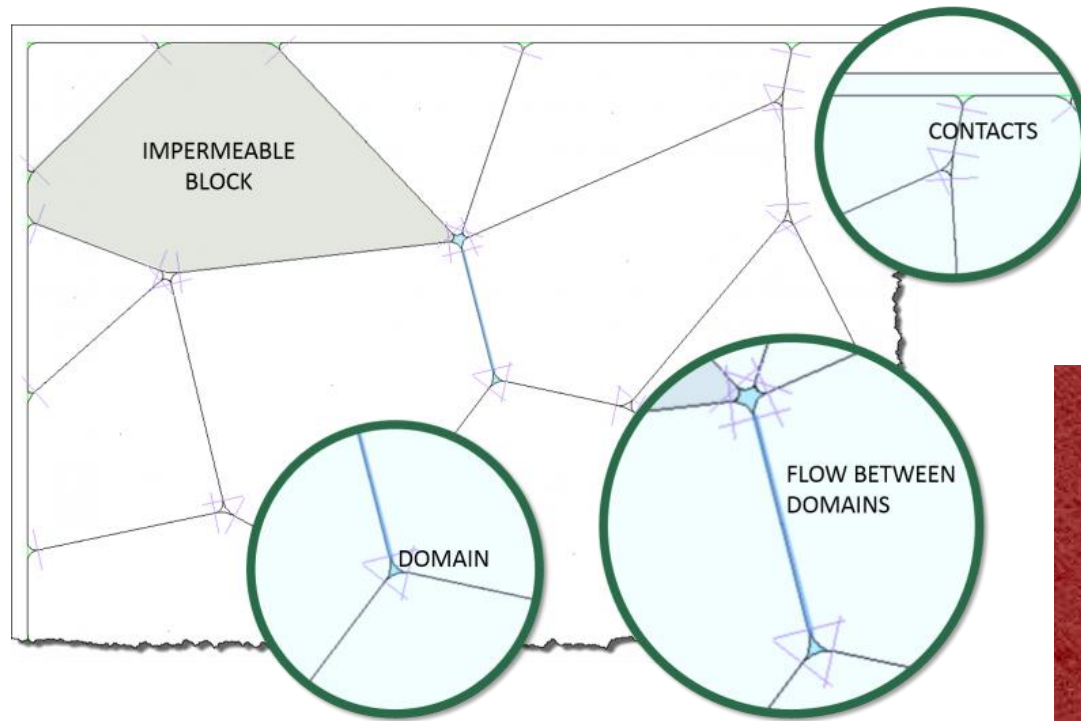
UDEC & 3DEC

- Developed to model rock masses in which joints control the mechanical behavior.
 - Easy to add any number of discontinuities
 - Direct integration of rigid body mechanics
- Rigid or deformable blocks...
- ... which interact via contact constitutive behavior
- Joint and matrix fluid flow
- Dynamic, thermal, creep & structural interaction
- Full coupling

UDEC Discrete Blocks



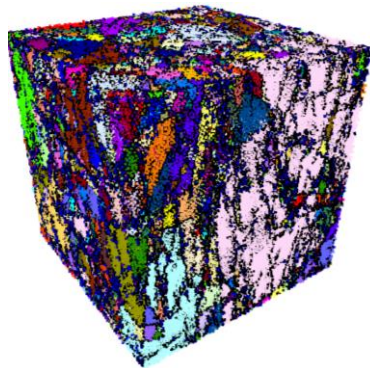
UDEC Joint fluid flow



Limitation: Discontinuities must be predefined

PFC

- Rigid sphere discrete element code
- Particle bonding – modeling intact rock, fracturing and flow of granular material.
- Fracture growth and interaction with existing fracture networks.
- Coupled Fluid flow, thermal, multi-physics.



Limitation: Research code, less “solution oriented”

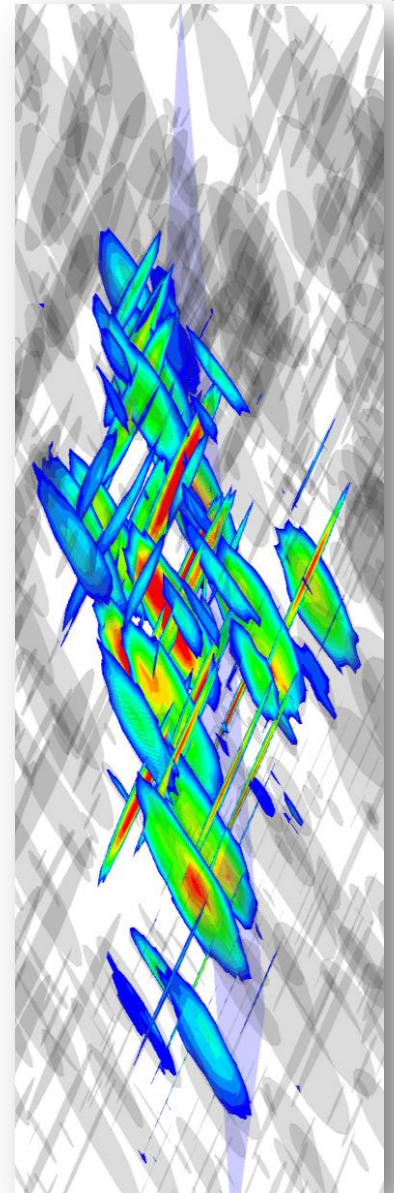


ITASCA™

APPLICATION TO EGS RESERVOIRS

Approach

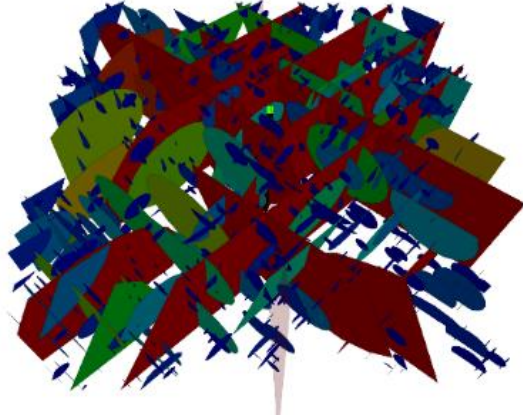
- DFN realizations represented explicitly in 3DEC
- Stimulation phase of EGS is modeled using hydro-mechanical response of the DFN to fluid injection
- Sensitivity of stimulation is performed for:
 - DFN characteristics
 - Different open-hole completion lengths along the borehole
- Model responses are compared quantitatively and qualitatively, in terms of a series of indices



DFN Realizations

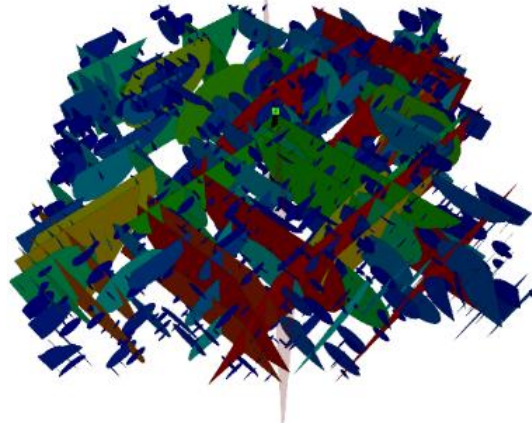
Case 1 DFN

$\alpha = 3.5, l_{max}$ is uncapped



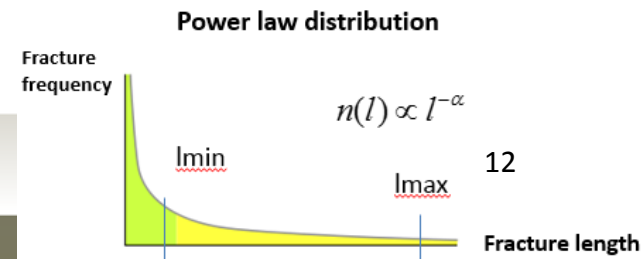
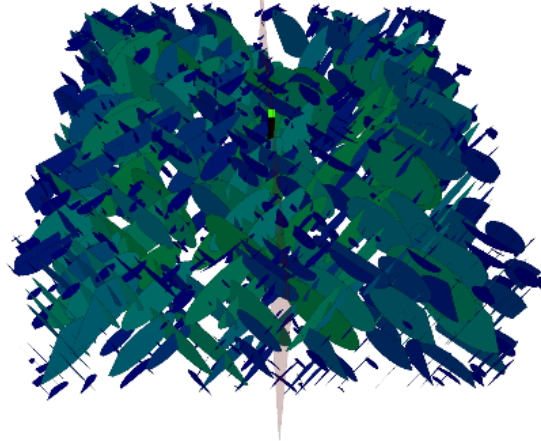
Case 2 DFN

$\alpha = 4.0, l_{max}$ is uncapped



Case 3 DFN

$\alpha = 3.0, l_{max} = 220 \text{ m}$



Evolution of apertures in Case 1

Hydraulic Fracture
connected borehole and
DFN fractures

20 m borehole

30 min

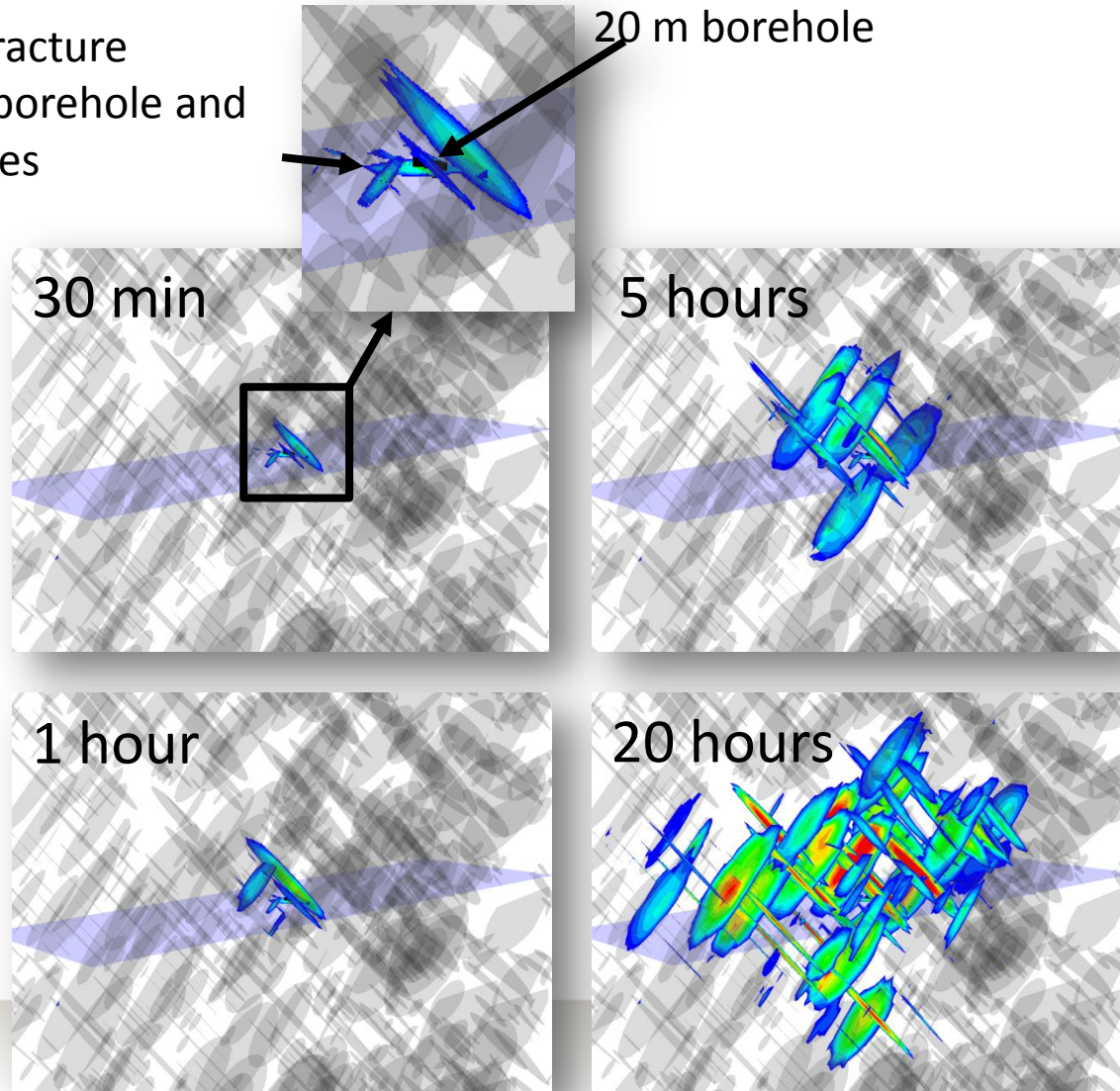
5 hours

1 hour

20 hours

Evolution of apertures in Case 3

Hydraulic Fracture
connected borehole and
DFN fractures



3DEC DP 5.10

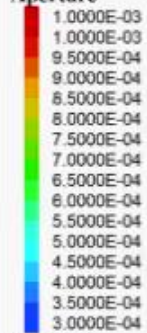
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Step 15397

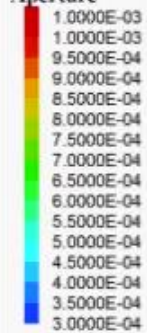
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injection time: 0.0637887 hours

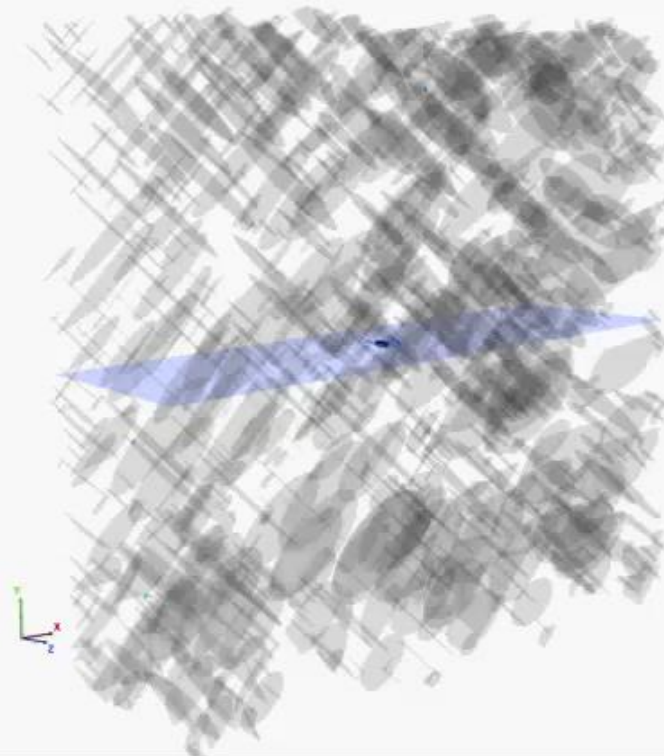
Aperture



Aperture



Aperture



Conclusions

- Fluid flow propagation in low permeability reservoirs highly depend on DFN characteristics.
- The presence of large fractures can cause localized flow and asymmetrical shapes of stimulated volume. Asymmetric responses to hydraulic fracturing is frequently reported by recorded microseismic data.

Summary of 2D Case Studies

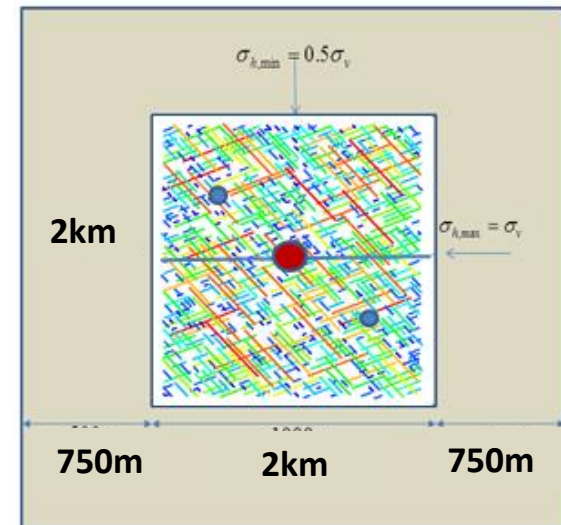
New studies are performed with respect to

- Effect of well positioning
 - Relative to fracture orientation
 - Injection-production well distance

Previous studies are repeated in 2km by 2km DFN with different well spacing, well positioning, and longer stimulation periods:

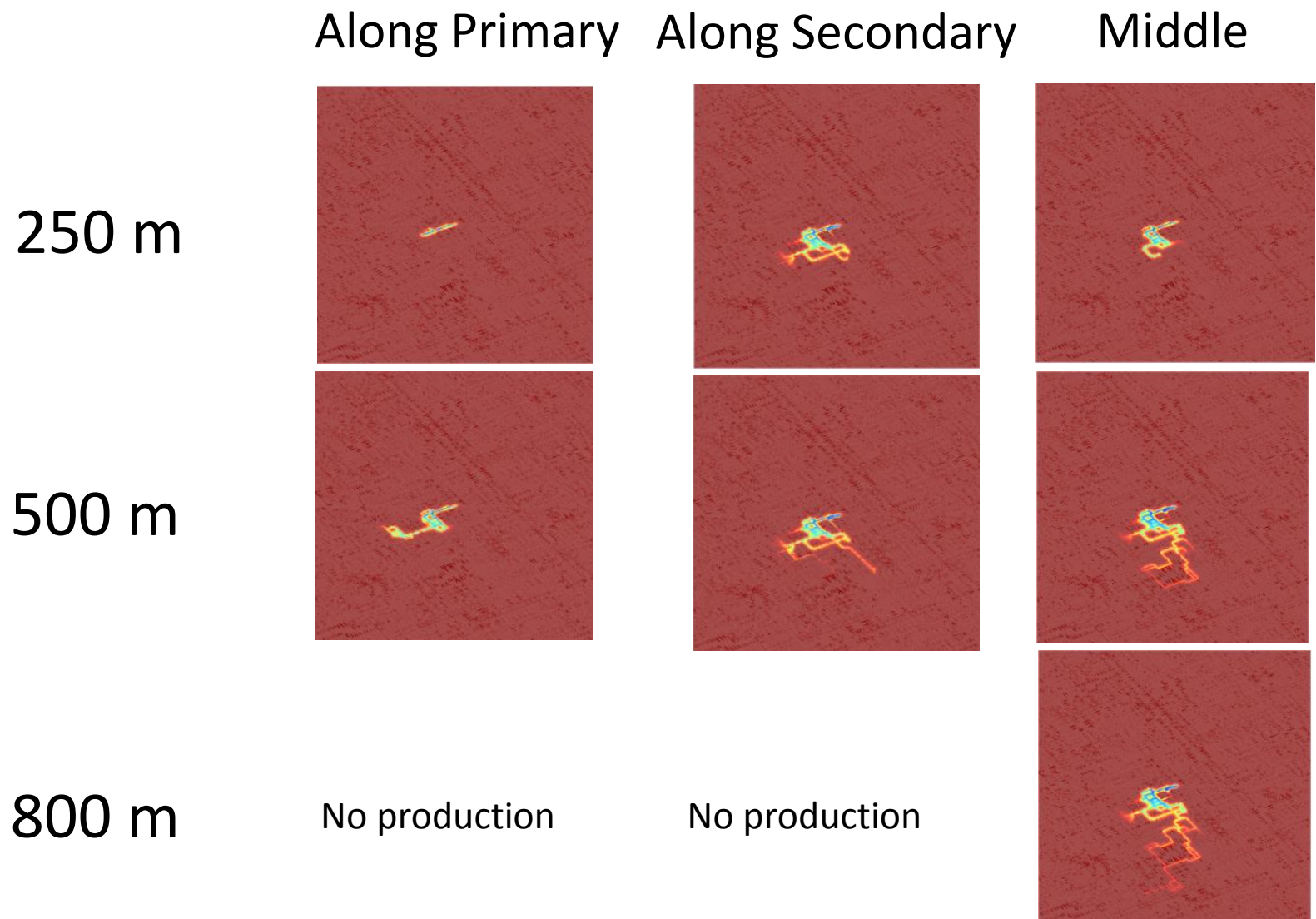
- Effect of fracture spacing/density
- Effect of production rate
- Effect of exponent of fracture size
- Effect of fracture orientation
- Effect of stimulation rate
- Effect of stiffness
- Effect of stimulation rate history

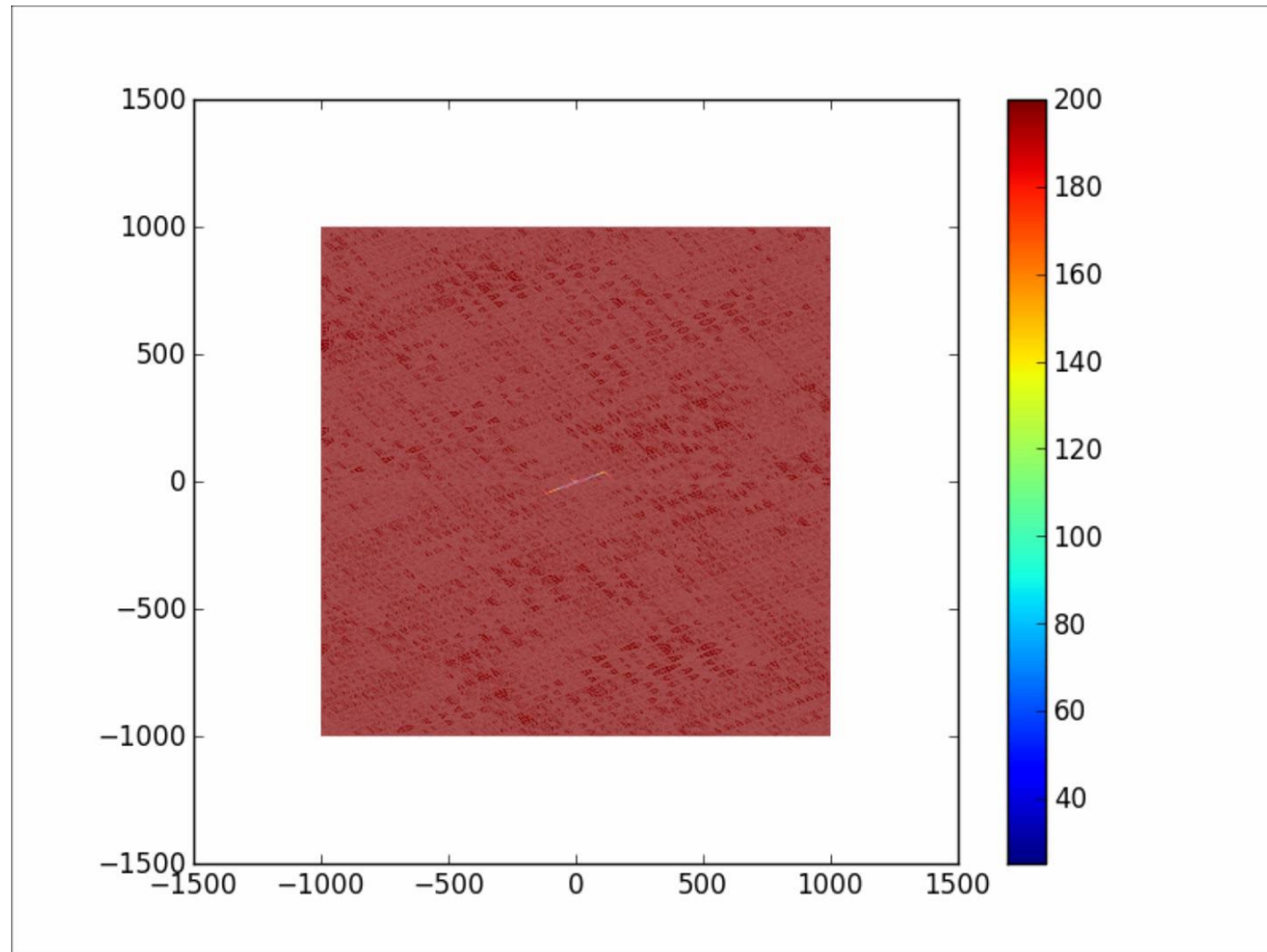
Schematic representation of UDEC model



Model Setup

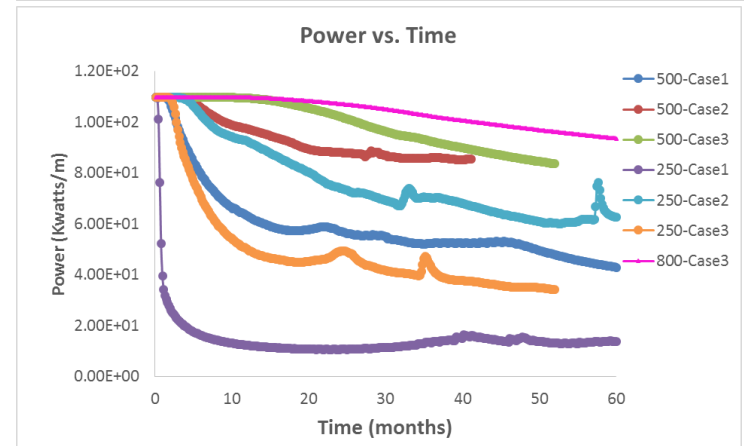
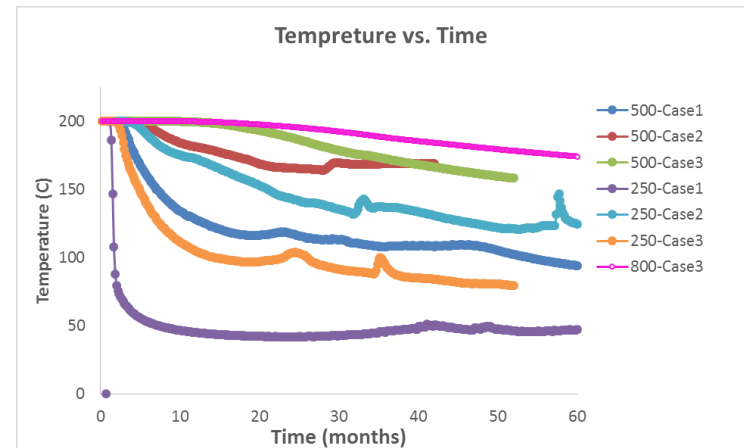
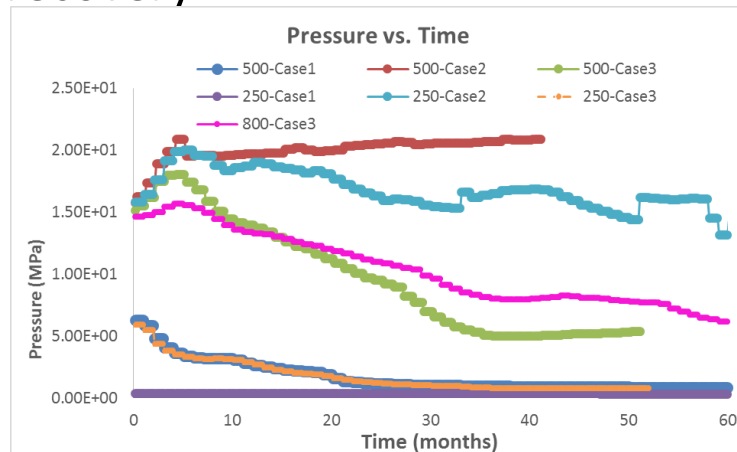
- Two preexisting joint sets
 - 160° and 45° to major principle stress
 - Stress ratio of 0.5
 - Open and conductive at $t=0$
 - Apertures: $3e-5m$ and $1e-5m$
- Model
 - Fracture flow only
 - Impermeable elastic blocks
 - 30° friction angle and 7.5° dilation



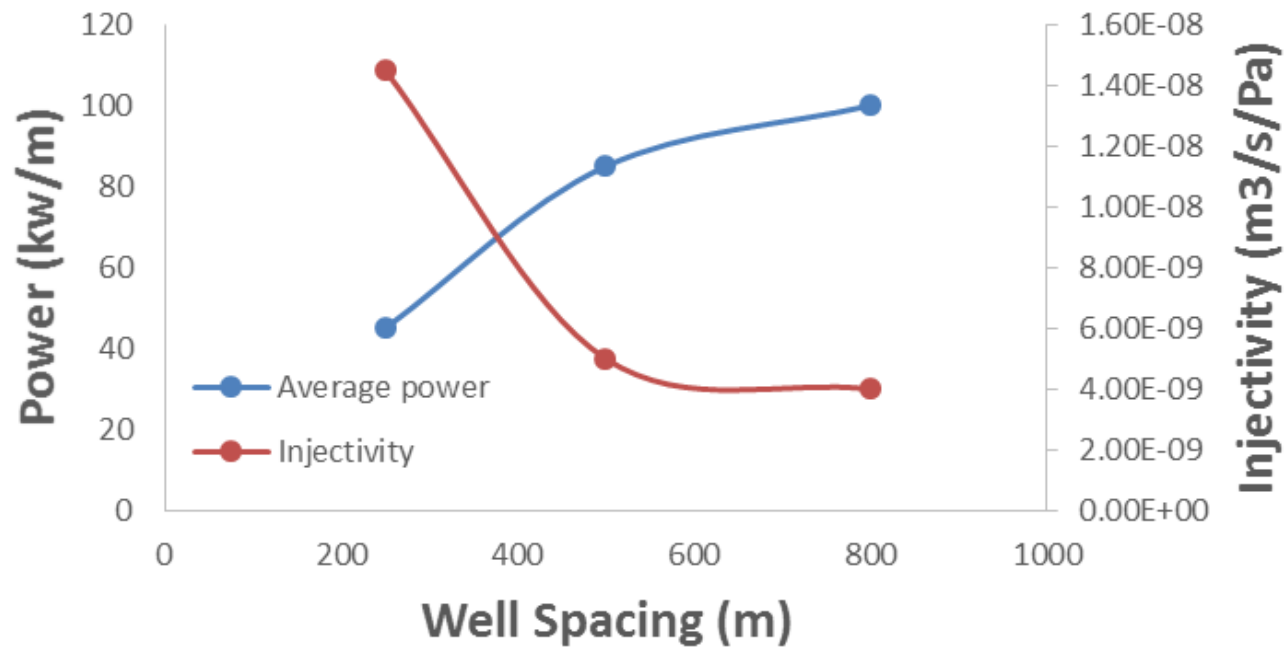


Production Indices

- Case I shows the quickest temperature draw-down
- Case III shows the slowest temperature draw-down
- In case we spacing of 800 m only one case was producing
- The cases compared have 100% recovery



Effect of injection-Production Well Spacing



Observation

- Positioning of the wells off the primary path is effective.
- Increasing the well distances is the most effective way of reducing temperature draw-down; however, injectivity decreases and the potential of loss of fluid increases.

Thank You